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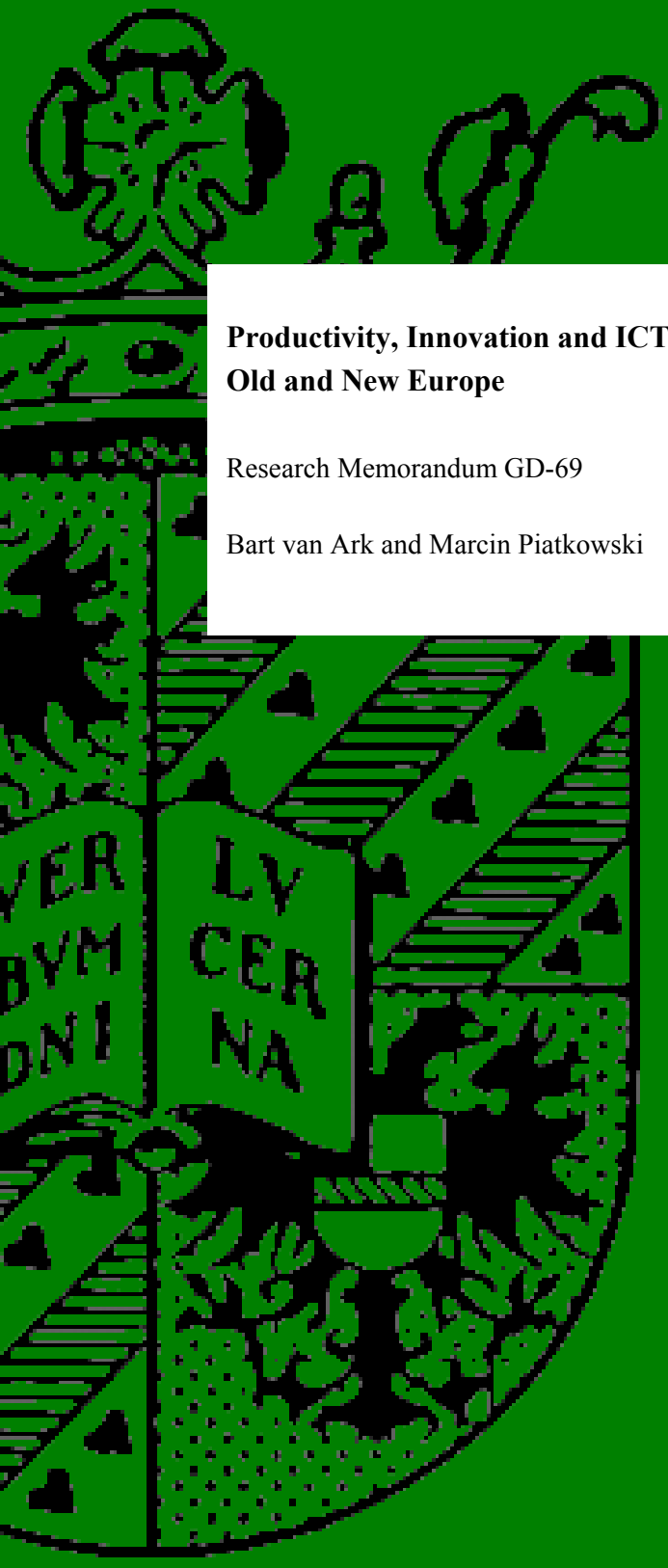

Productivity, Innovation and ICT in Old and New Europe

Research Memorandum GD-69

Bart van Ark and Marcin Piatkowski

RESEARCH MEMORANDUM

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Productivity, Innovation and ICT in Old and New Europe*

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Abstract

This paper investigates the productivity performance of CEE countries vis-à-vis the EU-15 during the 1990s to detect sources of convergence between the two regions. The paper shows that changes in labour intensity have been an important source of productivity convergence during the 1990s, and are likely to remain so in the near future. It is also found that despite lower income levels, ICT capital in the CEE-10 has contributed as much to labour productivity growth as in the EU-15. Industry analysis shows that manufacturing industries that have invested heavily in ICT have been key to the restructuring process. As such ICT may therefore have been an important but probably temporary source of convergence. In the longer run the impact of ICT on growth will have to come primarily from its productive use in services. The paper therefore includes a New Economy Indicator that reflects the existence of conducive environment for continued ICT investment and diffusion. It shows that further reforms are much needed for CEE countries to enter a second convergence phase in the coming decades.

JEL codes: O31, O47, O52, P27

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1. Introduction

Following the collapse of the Berlin Wall and the transition of the economies of Central and Eastern Europe (CEE) from socialist centrally planned to a market economy, a new phase in the transition process may soon begin for many of the CEE countries. As of 1 May 2004, eight CEE countries (as well as Cyprus and Malta) will become full members of the European Union. In addition, two CEE countries (Bulgaria and Romania) are candidates for entry at a later stage.

As a result of these developments, comparisons of economic performance between the CEE countries and the present EU-15 as well as between the enlarged EU-25 and the U.S. become of increasing interest.[1] In this paper our focus is on one important comparative aspect of economic performance, which is the impact of technological change on output, employment and productivity growth in various countries and regions. We concentrate on the impact of the rise in the production and use of information and communication technology (ICT) in individual countries. Our analysis will primarily deal with comparisons between CEE countries and EU-15 countries, but we will also use the U.S. experience as a benchmark of "state of the art" practices in exploiting ICT to generate productivity growth.

The analysis in this paper will be placed in the framework of the catch-up and convergence hypotheses. Irrespective of the political motives of its messenger, the distinction between "Old Europe" and "New Europe" by the U.S. secretary of defense, Donald Rumsfeld, appears quite useful from the perspective of analyzing ICT in the framework of catch up and convergence. Essentially we aim to shed light on which of the following hypotheses holds up best following the analysis in this paper:
The convergence (or even leapfrogging) hypothesis: "The new economy in New Europe and the Old Economy in Old Europe"; or
The divergence (or falling behind) hypothesis: "The old economy in New Europe and the new economy in Old Europe".

At face value there are arguments in favour of both hypotheses. The *convergence hypothesis* would be supported by the "advantages of backwardness"-literature, in particular Gerschenkron (1962) and Abramovitz (1986). In this light, CEE countries would benefit from the combination of rapid technology (ICT) diffusion and major restructuring of (in particular) the manufacturing sector. Indeed Central and Eastern Europe would then follow the path of East Asia over the past decades (van Ark and Timmer, 2003). The convergence hypothesis would be even more likely if the EU-15 countries get stuck on a "low-productivity growth" track, partly due to insufficient effect from ICT investment on productivity growth, due to rigid product and labour markets, too much emphasis on cost competitiveness, failing innovation systems and lack of competition (Nicoletti and Scarpetta, 2003).

Alternatively the *divergence hypothesis* derives support from the development towards comparative advantages in CEE countries in low- and medium tech manufacturing industries (e.g. food

[1] A useful empirical review comparing productivity and competitiveness in CEE countries vis-à-vis the EU-15 can be found in the *European Competitiveness Report 2003*, Chapter 4. See also Landesmann (2000), European Commission (2003), Havlik (2003) and Piatkowski (2002).

manufacturing) on the basis of cost competitiveness, insufficient diffusion of new technologies from the foreign-dominated to the domestic part of the economy, and from manufacturing to services. Furthermore the EU-15 may ultimately succeed to exploit the productivity potential from ICT, as there are clear indications that the ICT impact on productivity comes with some delay, in particular in the ICT-using sectors of the economy. This could mean that at least for the next decade or so, divergence in economic performance between CEE countries and the EU-15 would be more likely.

The paper proceeds as follows. In Section 2 we show the convergence trends between CEE, EU-15 countries and the U.S. in terms of average productivity and average per capita income since 1995.[2] The difference between the two measures indicates the impact of changes in labour intensity in the convergence process. Indeed a substantial part of the productivity recovery in CEE countries since the mid-1990s has been due to large cuts in employment and a decline in labour participation rates. In the EU-15, labour participation has significantly improved during the 1990s but at the same time productivity growth slowed down. We investigate various indicators of labour intensity to assess whether differences between CEE countries and the EU-15 are likely to continue to be a source of convergence in the future.

In Section 3 we zoom in on the drivers of labour productivity growth, and use a growth accounting framework to establish the contributions from investment in capital, in particular ICT capital, and total factor productivity (TFP) growth. In particular we look at whether ICT capital, which is the main asset embodying new technology, has been a source of convergence or divergence between CEE countries and the EU-15.

In Section 4, the paper adopts an industry perspective by using an industry taxonomy that distinguishes between industries that are typical ICT-producing industries, those that are intensive users of ICT as indicated by their ICT capital share, and those that are less intensive users of ICT. Within each group we distinguish between manufacturing and service industries in order to observe which industry groups show the fastest growth rates in terms of labour productivity.
In Section 5 we broaden our analysis by comparing our results from Sections 3 and 4 with a "New Economy Indicator" for each country, which reflects the development of institutional and economic infrastructure, trade openness and innovation (Piatkowski, 2002). The relationship between the productivity results from ICT and the New Economy indicators provide an insight into how the economic environment can contribute to the realization of growth potential of the 'new economy' in both New and Old Europe

Section 6 concludes on the characteristics of the convergence process up till now, and how – based on the observations hitherto as well as the comparative experience in Western Europe and the U.S. – it may continue or change in nature during the coming period. Although our conclusions generally give more support to the convergence hypothesis than to the divergence hypothesis, we argue that the

[2] This relatively short period is used because the estimates for the first half of the 1990s are rather unreliable due to the immediate effects of the system shock in 1989/1990 and because of the substantial change in measurement methods of national accounts in CEE countries between 1991 and 1995. See http://www.ggdc.net/dseries/totecon.html for longer time series.

convergence process may slow down as the productive implementation of ICT in services is more complicated and requires bigger changes in the economic environment of CEE countries.

2. Convergence and labour input during the 1990s

Output and productivity growth in CEE countries has shown a U-turn since 1990. Between 1989 and 1992 output collapsed and per capita income fell by more than 20%. Labour productivity declined somewhat less (by around 10%) because the decline in output was to some extent offset by a rapid shakeout of unproductive activities (van Ark, 1999). Since 1992/1993 productivity growth has rapidly turned around as a result of a recovery in output growth and a continued decline in employment. The restructuring process has led to a continued process of shutting down of inefficient firms in CEE countries as well as to opening up new businesses with faster output growth compared to incumbent firms.

Table 1 shows that from 1995-2000 average annual GDP growth in the CEE- countries was 2.9 per cent on average, which was 0.6 percentage points higher than average GDP growth in the EU-15. On average, GDP growth in the enlarged European Union (as of 1 May 2004) comes at 2.4 per cent.[3]

Table 1: Growth of Real GDP, GDP per Capita, Labour Productivity and Working Hours, 1995-2002

	Real GDP	GDP per head of population	GDP per person employed	Employ-ment
EU-15	2.3	2.1	1.0	1.3
CEE-10	2.9	3.1	3.9	-1.0
EU-25	2.4	2.2	1.4	1.0
United States	3.2	2.1	2.0	1.2

Note: for country detail, see Appendix Table 1
Source: McGuckin and van Ark (2004); see also **www.ggdc.net/dseries/totecon.html**

The difference in per capita income growth between the two regions is somewhat bigger than for real GDP, i.e. at 1 percentage point (2.1 per cent in EU and 3.1 per cent in the CEE-10). However, labour productivity growth, measured as output per person employed, differs by as much as 2.9 percentage points between the two regions. Whereas productivity growth in the EU-15 comes at no more than 1.0 per cent per year on average, the 10 CEE countries realized on average 3.9 per cent growth between 1995 and 2002.[4] Hence the relatively strong productivity convergence between the CEE-10 and the EU-15 is for only 20 per cent driven by faster output growth in the CEE-countries and for 80 per cent by job cuts.

[3] The EU-25 will consist of the present 15 EU member states, including the CEE-10 countries excluding Bulgaria and Romania, and including Cyprus and Malta.
[4] On www.ggdc.net estimates are also shown in terms of output per hour worked. The hours estimates, however, are based on figures for a limited number of countries (Czech Republic, Hungary and Slovakia). See also Table 3.

Table 2 shows that despite rapid productivity growth, the gap in productivity level between CEE-countries and the EU-15 is still quite large. Between 1995 and 2002 the productivity gap between the two regions reduced by only 8.2 percentage points. In 2002 the average productivity level of the CEE-10 was still at only 45.6 per cent of the EU-15. Only Slovenia has productivity levels that are near those countries in the EU-15 with the lowest productivity levels, i.e. Portugal and Greece. Hence the period for catch-up to even the low-productivity echelon of the present EU-15, will still be considerable for large countries like Poland and Romania (see also van Ark, 1999).

Table 2: Relative Levels of GDP per Capita and GDP per Person Employed, 1995-2002

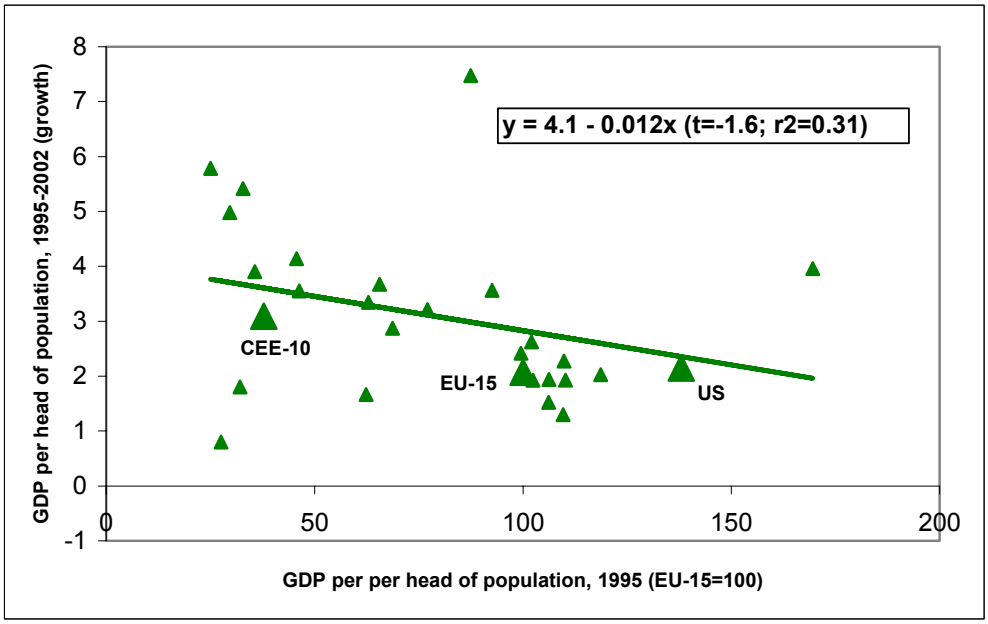
	GDP per head of population (EU-15=100)		GDP per person employed (EU-15=100)	
	1995	2002	1995	2002
EU-15	100.0	100.0	100.0	100.0
CEE-10	37.8	40.6	37.4	45.6
EU-25	90.2	91.2	90.1	92.5
United States	138.0	138.7	118.3	126.6

Note: for country detail, see Appendix Table 2; relative levels are converted at 1999 EKS PPPs (OECD)
Source: McGuckin and van Ark (2004); see also **www.ggdc.net/dseries/totecon.html**

The per capita income and labour productivity measures can be analyzed in the light of the convergence hypothesis. This is done by combining Tables 1 and 2 through relating the relative levels for each country to the EU-15 average in the beginning year of the period (1995) to their subsequent growth rates from 1995-2002. Figure 1 shows that there is a slight negative but not significant relationship found for per capita income. For labour productivity a stronger negative relationship is found than for per capita income and the relationship is now statistically significant with a fairly higher correlation (Figure 2).[5]

[5] All statistical tests include the United States.

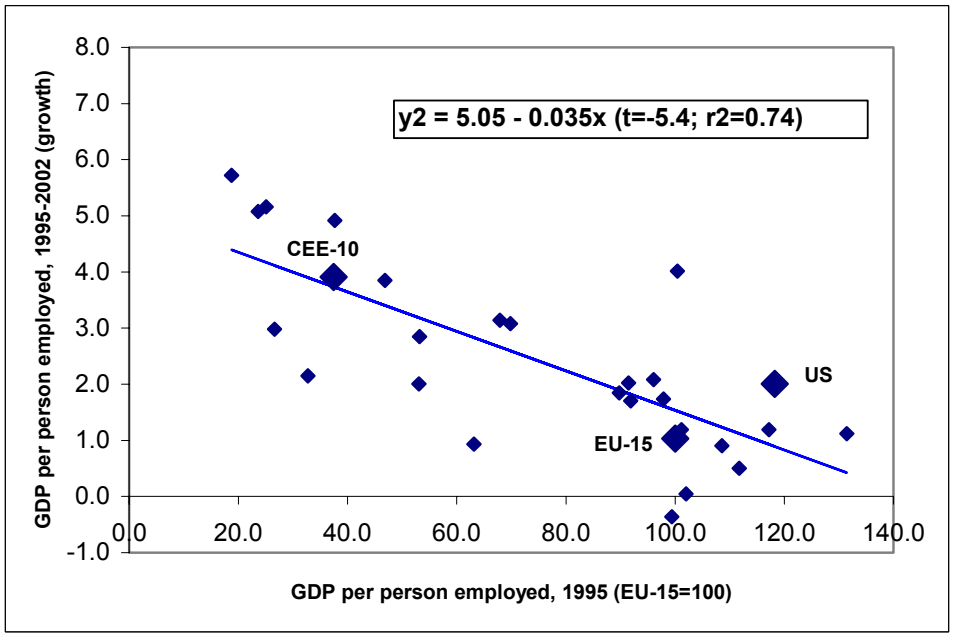
Figure 1: Relationship between Per Capita Income Level relative to EU-15 (1995) and Per Capita Income Growth (1995-2002)



Note: for country detail, see Appendix Tables 1 and 2; relative levels are converted at 1999 EKS PPPs (OECD)

Source: McGuckin and van Ark (2004); see also **www.ggdc.net/dseries/totecon.html**

Figure 2: Relationship between Level of GDP per Person Employed relative to EU-15 (1995) and Growth of GDP per Person Employed (1995-2002)

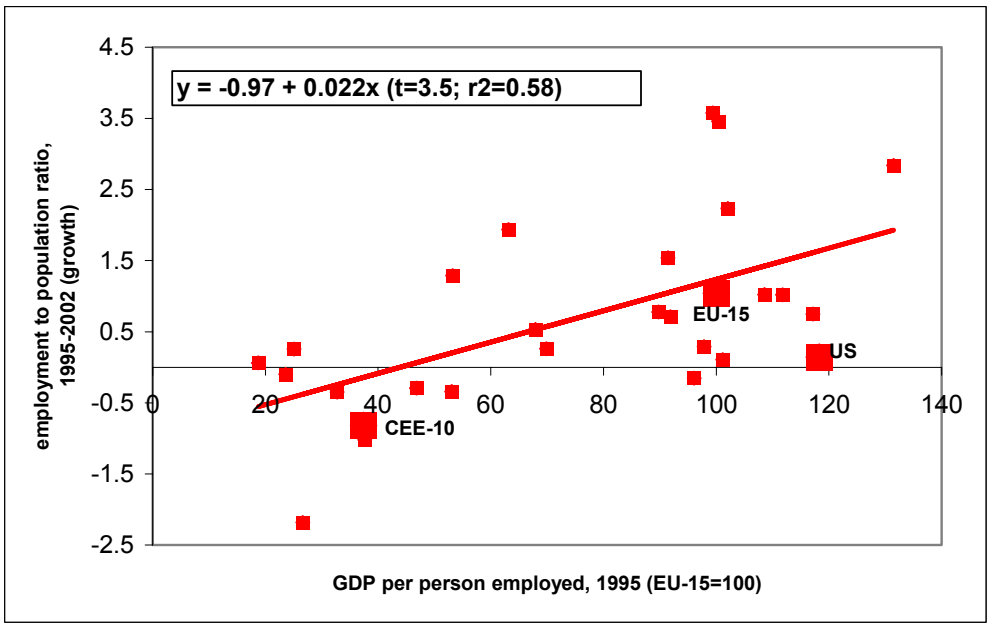


Note: for country detail, see Appendix Tables 1 and 2; relative levels are converted at 1999 EKS PPPs (OECD)

Source: McGuckin and van Ark (2004); see also **www.ggdc.net/dseries/totecon.html**

The lack of significance for the relationship of the level of per capita income vis-à-vis growth is due to the fact that is not only affected by labour productivity, but also by labour intensity – more precisely by the employment to population ratio. Figure 3 shows that the change in the employment to population ratio is positively related to the level of labour productivity in the CEE-10 and the EU-15. Since 1995 the CEE-countries have generally shown negative or very small increases in the employment to population ratios. It has therefore strengthened labour productivity convergence, but weakened the relationship between average income level and per capita income growth. At lower income levels the "cake" has been produced with an increasingly smaller number of people relative to the total population.

Figure 3: Relationship between Level of GDP per Person Employed relative to EU-15 (1995) and Change in Employment to Population Ratio (1995-2002)



Note: for country detail, see Appendix Tables 2 and 3
Source: McGuckin and van Ark (2004); see also www.ggdc.net/dseries/totecon.html

To establish whether labour saving will continue to be an important source for the productivity convergence process, Table 3 shows three measures of labour intensity. The first measure is the same as in Figure 3 and represents the ratio of employment to population for 1995 and 2002. This measure is directly obtained from the difference in the growth rates and comparative levels of per capita income and GDP per person employment. The employment to population ratio shows a slight increase for the EU-15 and a modest decline in CEE-10. The level of employment to population is also considerably lower in CEE-10 than in EU-15, suggesting a divergence in the realization of labour potential in both regions.

Table 3: Employment-Population Ratios, Labour Force Participation Rates and Total Hours to Potential Hours (a), 1995 and 2002

	Employment to Population Ration (%)		Labour Force to Population 15-64 yrs		Total Hours to Potential Hours (%) (a)	
	1995	2002	1995	2002	1995	2002
EU-15	0.404	0.435	0.678	0.704	0.349	0.367
CEE-10	0.370	0.350	0.687	0.654	0.462	0.422
EU-25	0.405	0.428	0.680	0.693	0.374	0.379
United States	0.472	0.476	0.777	0.759	0.480	0.477

Potential hours are based on working age population times 2,800 working hours per year
Note: for country detail, see Appendix Table 3.
Source: Groningen Growth and Development Centre (www.ggdc.net) and OECD *Labour Force Statistics* (various issues) and Eurostat, *Employment in Europe 2003*

The second measure, which is the ratio of the labour force to the total population of working age (15-64 years), shows similar trends as the first measure. Whereas labour force participation in the CEE countries was still higher than in the EU-15 by 1995 but has fallen below the EU-15 level by 2002.[6] However, the differences remain somewhat smaller than for the employment to population ratio, which suggest that part of the underperformance of the CEE countries in terms of labour intensity is due to a rising non-working age population relative to the EU.

The third measure in Table 3 is an indicator of the degree to which the potential of labour has been realized. Potential labour intensity is derived from the product of the total working age population times 2,800 annual hours (which is equal to a 6-day working week at 9 hours per day).[7] Obviously the latter measure is not meant to formulate a target which countries should strive for. It merely serves as a benchmark against which the actual number of working hours can be compared. The estimates confirms that the realization of the labour potential in the EU-15 has improved since the mid-1990s, whereas it deteriorated for CEE countries. Unlike the two other labour market indicators, the latter measure also suggests convergence rather than divergence of labour intensity, because the level in the CEE countries is still higher than for the EU-15.

From the perspective of convergence analysis, the measure of realized labour potential may be the most adequate measure of labour intensity. If one assumes that there is still scope for the EU-15 countries to increase labour intensity further, while labour intensity in the CEE countries may still decline somewhat further due to restructuring, these two processes will continue to drive part of the convergence process of labour productivity of CEE countries on the present EU-15 for the next decade or so.

[6] Appendix Table 2 shows a wide variation in labour force participation rates, with relatively low levels for Hungary and Romania and relatively high levels in the Baltic states in 2002.
[7] See footnote 4 for a comment on the measure of working hours for the CEE countries. See van Ark, Frankema and Duteweerd (2003) for the concept of potential working hours.

3. The Contribution of ICT Capital to Growth

An important question that arises is how the labour saving process has been translated into productivity growth in Central and Eastern Europe during the 1990s. Throughout the process of restructuring, productivity growth may have been driven by a rise in capital intensity but it may also have been supported by technical change. In particular when increased investment took place in new types of capital, such as Information and Communication Technology (ICT) capital, it may have been a major source of accelerated productivity growth. An important issue, however, is to what extent ICT capital directly contributes to labour productivity growth, and to what extent it works through total factor productivity growth by industries that either produce or use ICT capital intensity intensively. Indeed during the 1990s, ICT capital has been a more important source of growth in the "old" EU countries during the 1990s than ICT-related TFP growth.[8]

This issue is all the more important from the perspective of catch-up growth as has been already discussed earlier in the light of East Asian growth during the past decades. For example, Krugman (1994) and Young (1995) indicated that most of growth in the Asian was driven by increases in capital intensity rather than by TFP growth. Unfortunately, detailed work on the role of ICT, using growth accounting techniques, for new and non-OECD countries is still limited, but the evidence available so far suggests an impact from ICT capital although there is much variation.[9]

As far as the CEE countries are concerned, Piatkowski (2003a) provides a detailed study of ICT and growth in Poland. In this section we report and compare updated results on the contribution of ICT capital to output and labour productivity during 1995-2001 from Piatkowski (2003b), which includes Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia, and from Timmer et al. (2003) for the EU-15 and the US.[10]

A detailed description of the methodology to measure the contribution of ICT to output and labour productivity growth is provided in several of the studies quoted above and can be summarized as follows. Gross domestic product (Y) is produced from aggregate factor input X, consisting of capital services (K) and labour services (L). Productivity is represented as Hicks-neutral augmentation of aggregate input (A). The aggregate production function takes the form:

$$Y = A * X(L, K_n, K_{it}) \qquad (1)$$

with subscript *n* indicating services from non-IT capital and subscript *it* indicating services from information technology capital (including office and computing equipment, communication equipment and software). Under the assumption of competitive factor markets and constant returns to scale, growth accounting expresses the growth of output as a share weighted growth of inputs and total factor productivity, denoted by A, which is derived as a residual.

[8] See, for example, Jorgenson (2004) for the G7, Colecchia and Schreyer (2001) for OECD; and Daveri (2002) and van Ark, Timmer and Ypma (2003) for the EU.

[9] See, for example, Lee and Kahtri (2003) for an ICT growth accounting study for Asia.

[10] Piatkowski (2003b) also includes estimates for Russia, which are left out here in order to focus the analysis on the CEE-10. Compared to Piatkowski (2003b) the updated capital series are for non-residential capital only and were extended to cover year 2001. In addition, whenever possible the data was complemented with aggregate investment series from World Bank *World Development Indicators 2000* (CD-ROM).

$$\Delta \ln Y = v_L \Delta \ln L + v_{Kn} \Delta \ln K_n + v_{Kit} \Delta \ln K_{it} + \Delta \ln A \qquad (2)$$

where v's denote the average shares in total factor income and because of constant returns to scale: $v_L + v_{Kn} + v_{Kit} = 1$, and Δ refers to first differences. By rearranging equation (2) the results can be presented in terms of average labour productivity growth defined as $y = Y/L$, the ratio of output to employment, $k = K/L$, the ratio of capital services to persons employed and TFP:

$$\Delta \ln y = v_{Kn} \Delta \ln k_n + v_{Kit} \Delta \ln k_{it} + \Delta \ln A \qquad (3)$$

Table 4 shows that between 1995 and 2001 the contribution of ICT capital to labour productivity growth ($v_{Kit} \Delta \ln k_{it}$) in CEE countries in absolute terms was comparable to that in the EU-15, despite lower levels of productivity in the former (column 3). This relatively high contribution from ICT capital in the CEE countries has been due to a rapid acceleration in real quality-adjusted ICT investments, which were growing between 1995 and 2000 at an average rate of between 24% and 39% a year. During the same period, real investment in ICT increased at 18.5% and 19.3% on average in the EU and the US respectively.

In both the CEE and EU countries high growth rates of ICT investment have been induced by rapidly falling prices of ICT products and services, which encouraged firms to substitute ICT for non-ICT capital. In the case of the CEE countries, the rapid build-up of the ICT capital stock was also driven by a large pent-up demand for ICT infrastructure. This was partly due to the legacy of a technology gap that arose before 1989 under the socialist system due to NATO-imposed restrictions on imports of technologically advanced equipment and low levels of ICT investment.[11] In addition, the restructuring process since transition created typical catch-up growth in ICT capital intensity.[12]

[11] Until 1990/1991 imports of high-technology products to former socialist countries was restricted under the so-called COCOM (Coordinating Committee) restrictions enforced by NATO to prevent diffusion of dual use civilian-military high-tech equipment in the member countries of the Warsaw military pact.

[12] For instance, the mainline telephone penetration in Poland in 1990 amounted to only 11 lines per 100 inhabitants. By the end of 2003, it increased to some 32 mainlines and more than 40 mobile telephone lines (Polish Statistical Office, 2003).

Table 4: ICT capital contribution to labour productivity growth (GDP per person employed) in CEE countries, EU-15 and the U.S., 1995-2001, in %-points

	GDP per person employed (annual growth, %)	%-point contribution of:			Relative ICT capital share in LP growth (%)
		Non-ICT capital intensity	ICT capital intensity	Total factor productivity growth	
	(1)	(2)	(3)	(4)	(5)
CEE countries	**3.5**	**1.0**	**0.6**	**2.0**	**17%**
Slovakia	4.8	1.4	0.6	2.8	12%
Poland	4.4	1.8	0.6	2.1	13%
Slovenia	3.8	0.7	0.5	2.5	14%
Romania	3.5	1.4	0.3	1.8	7%
Hungary	3.3	0.2	0.7	2.4	22%
Czech Republic	2.8	1.4	0.8	0.6	27%
Bulgaria	1.9	-0.1	0.5	1.6	26%
European Union	**1.1**	**0.4**	**0.4**	**0.3**	**36%**
Ireland	4.0	0.6	0.6	2.7	15%
Greece	3.2	1.1	0.5	1.7	15%
Austria	2.3	0.9	0.4	1.0	16%
Finland	2.2	-0.6	0.6	2.2	28%
Sweden	1.8	0.5	0.8	0.6	42%
Denmark	1.6	0.9	0.6	0.2	38%
United Kingdom	1.5	0.6	0.6	0.4	39%
Portugal	1.5	1.1	0.3	0.1	21%
Belgium	1.4	0.3	0.6	0.5	46%
Germany	1.2	0.3	0.3	0.5	30%
France	1.0	0.3	0.3	0.4	31%
Italy	0.8	0.5	0.4	0.0	46%
Netherlands	0.3	-0.2	0.4	0.0	164%
Spain	-0.3	0.1	0.2	-0.6	-51%
United States	**2.2**	**0.4**	**0.7**	**1.1**	**34%**

Source: updated results from Piatkowski (2003b) for CEE countries (with adjustment to non-residential capital and extension to year 2001) and Timmer et al. (2003) for the EU countries and the US. CEE represents an unweighted average

As equation (3) above shows, the contribution of ICT capital to labour productivity growth is not only determined by the growth in ICT capital stock, but also by the share of ICT capital in total capital compensation. On average share of ICT capital in total factor input compensation was 2.1 per cent between 1995 and 2000 compared to 3.3 per cent in the EU-15 and 5.7 per cent in the U.S.

(Piatkowski, 2003b; Timmer *et al.*, 2003). Nevertheless rapid growth in ICT capital more than offset the lower compensation shares in CEE countries.

A glance at Figure 4, which relates the comparative level of GDP per person employed to the *absolute* ICT contribution to labour productivity growth, shows that ICT capital on itself has not been a direct source of convergence. However, lower labour productivity levels of the CEE countries also did not prevent them from benefiting from ICT capital to the same degree as the average for the EU, and it has therefore not been a cause for divergence either.[13]

Within the EU-15 two groups of countries can be distinguished from Figure 4. The first group of countries, including the Nordic countries, Ireland, the UK and Belgium, show a considerably stronger contribution from ICT capital than the other group, which includes France, German, Italy, Austria and the Netherlands. These differences may be related to differences in the environment in which ICT use is taking place (see Section 5).

Figure 4 also shows that, within the CEE-group, countries with higher labour productivity levels are characterised by a somewhat larger contribution of ICT capital. This implies that, provided CEE countries have reached a certain degree of industrial development, they have successfully used ICT to increase the growth rates in labour productivity to the same degree as the most ICT-intensive countries in the EU-15.

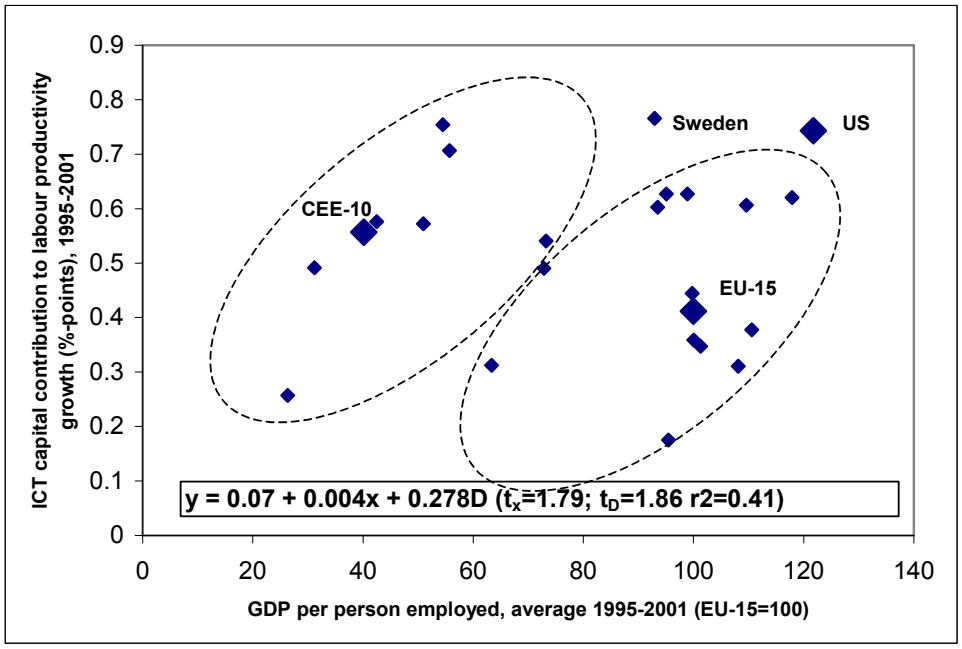
The most important source of convergence between the CEE-countries and the EU-15 comes is the higher contributions of total factor productivity in the former group (column 4 of Table 4). This result is in contrast to what was found for East Asia by Krugman (1994) and Young (1995), who suggested much slower TFP growth. Although the precise reasons for relatively high TFP growth are not known, these are likely to be strongly related to the effects of restructuring (privatization, emergence of new, more productive firms, liquidation of state-owned companies), technology transfer, higher capacity utilization, improvement in managerial and business skills, an increase in human capital and more entrenched macroeconomic stability. TFP growth may also have arisen from the productive exploitation of ICT capital, but its precise contribution cannot be directly determined. In any case it will then have been only one of the sources of convergence of productivity growth in CEE-countries relative to the average level of the EU-15.

While it is not possible to disentangle the productivity contribution from all factors, it can be safely argued that part of the rapid increase in labour productivity was driven by large scale privatization and liquidation of inefficient state-owned companies, a phenomenon mostly unique to countries transitioning from a centrally planned to a market economy.[14] Some other part of the growth in labour productivity stemmed from a cyclical effect of higher capacity utilization as (after 1995) most CEE

[13] The final column of Table 4 shows that the *relative* contributions of ICT capital to labour productivity growth were much lower for the CEE countries than for the EU-15 average (17% and 36% respectively) because of the higher growth rates of labour productivity itself in the CEE countries.
[14] Between 1990 and 2000, the share of the private sector in GDP in CEE countries increased from less than 10% to more than 60% of the total (EBRD 2003).

countries quickly recovered from the transitional recession, which shaved off from 18% to 40% of their GDP as of 1989 (Kolodko, 2000).

Figure 4: Contribution of ICT Capital to Labour Productivity Growth versus average GDP per Person Employed (EU-15=100), 1995-2001



Note: x refers to GDP per person employed level, D refers to a dummy for CEE countries
Source: See Table 4; GDP per person employed, see Table 2.

However, privatization and the surge in capacity utilization, which contributed to high labour productivity growth rates in the CEE countries, were mostly of a one-off nature. If these two factors could be disentangled from aggregate productivity growth, the relative contribution of ICT capital would most likely still be higher than in the EU-15 countries due to its own contribution to restructuring. Hence ICT can be seen as an important source of convergence between CEE-countries and the EU-15 during the 1990s.

4. The contribution of ICT-Production and ICT-use to Growth

The estimates in Section 3 provide a useful perspective on the contribution of ICT investment to productivity growth on the country level. The estimates suggest that in absolute terms the contribution of ICT capital to labour productivity growth in CEE countries is comparable to that in the EU-15 despite lower levels of productivity. In addition ICT may have contributed to the TFP growth, although the precise contribution cannot be quantified at this stage. This could be interpreted as a sign of ICT playing an important role in the convergence process.

However, before we can settle on these conclusions, we require a perspective on the role of ICT at industry level. For example, ICT contributions in CEE countries may have been largest in those parts of the economy that opened up to international competition (mainly under the influence of foreign direct investment) but are declining in relative importance for the economy as a whole. This development may be due to a restructuring process leading to the closure of old firms and new entry of only a small number of modern and internationally competitive plants. In that case the higher ICT contribution may have been a temporary phenomenon and not a sustainable source of convergence. Alternatively, the ICT contributions may be largest in firms that have been surviving and that are able to expand market shares in an international competitive environment due to an improved quality-price mix.

An industry taxonomy on the basis of ICT productivity and use

Because of the lack of ICT investment series at the industry level, it is not possible to locate the industries in which ICT capital contributes most to productivity growth.[15] An alternative approach therefore is to look at the labour productivity growth rates for three main groups of industries, namely those that can typically be characterized as ICT-producing industries, those that make intensive use of ICT and those that use ICT less intensively ("non-ICT" industries). The first group includes producers of IT hardware, communication equipment, telecommunications and computer services (including software), and was distinguished based on an OECD classification. The second and third groups are distinguished in terms of their intensity of use of ICT. This is a less straightforward undertaking since nearly every part of the economy uses some ICT. As a measure of ICT intensity, we rely on the share of ICT capital in total capital services in the United States. Using these data, the top half of industries are classified as ICT using and the bottom half as non-ICT.[16]

An obvious concern, of course, is whether the U.S. classification of industries can so easily be applied to other countries. This issue becomes of particular relevance when using it for the industry grouping in CEE countries, which are at a very different stage of industrial development than the U.S. economy.[17] Our assumption is that the distribution of ICT use in the U.S. presents a set of technological opportunities, which may or may not have been taken up in other countries. For future work it would be useful to check the sensitivity of this taxonomy for shifts of industries between the various industry groupings.

[15] See, for example, Jorgenson, Ho and Stiroh (2002) for an industry analysis for the U.S.; Inklaar, O'Mahony and Timmer (2003) for an industry analysis for France, Germany, the Netherlands and the United Kingdom. Some ICT-investment data by industry are also available for Slovenia, but these have not yet been used for this study.

[16] See van Ark, Inklaar and McGuckin (2003) for a detailed description of this methodology. The exceptions to the taxonomy are the education and health sectors which rank fairly high in terms of their ICT capital share, but near the bottom on alternative measures such as ICT capital per worker or per unit of output. Results are qualitatively similar if these industries were included as ICT-using, however.

[17] Based on the available evidence for some EU countries, Van Ark, Inklaar and McGuckin (2003) show that the rankings of ICT intensity across industries is reasonably similar in the U.S. and Europe. Indeed some industries, like transport and storage and textile products are classified as ICT-using in the U.S. but not in the EU. However, in contrast, an industry like chemical products is not classified as ICT-using in the U.S. but it would do so in the case of the EU.

The data

For the analysis of productivity growth at industry level we make use of the 60 Industry Database of the Groningen Growth and Development Centre, which contains information on value added and employment in a wide range of OECD countries from 1979 to 2001.[18] For this paper we developed estimates for four CEE countries, namely Czech Republic, Hungary, Poland and Slovakia for the period from 1993 onwards. The point of departure is the new OECD STAN Database on national accounts. The STAN Database contains information on the most important national accounts variables from 1970 onwards on a common industrial classification.[19] The level of detail has to be substantial to distinguish, for example, between various ICT-producing and ICT-using industries. STAN was therefore supplemented with industry detail from national production surveys and services statistics covering production industries, distribution and services. In general the method employed was to use the additional data to divide the STAN aggregates into sub-industries.

The series are adjusted for two important measurement problems, which are the method of aggregation and the deflation of ICT goods output. At present, many countries still use fixed-weight (Laspeyres) indices to calculate aggregate value added at constant prices. This can lead to substitution bias if the structure of the economy is changing over time. To ensure consistency across countries, we use Törnqvist aggregation to calculate chain-weighted indices for the aggregated real output series. This means that our estimates for GDP will generally not conform to those from national statistical offices.

Another problem is the deflation of ICT goods. It is well known that the technical capabilities of computers have improved tremendously over the past few decades. Since consumers can buy computers with vastly more computing power at comparable prices, the price of computing power has declined continuously. However, traditional methods of sampling and quality adjustment in calculating price indices for these goods will almost certainly lead to an underestimation in the rate of the output price decline. At present there are only a few countries, like the U.S., Canada and France, that have an adequate system in place for measuring prices of computers and semiconductors. This means that measured productivity growth in ICT producing industries in all other countries is likely to be understated. For the EU-15 countries, we avoid this downward bias by applying a harmonisation procedure, which consists of applying the U.S. deflators for each of the ICT producing manufacturing industries to all other countries after making a correction for the general inflation level.[20]

In the case of the CEE-countries, we have been more reluctant to make direct use of the U.S. hedonic deflators for ICT-producing industries. It is clear that the composition of production in the ICT-producing industries in countries other than the U.S., and in particular in the CEE countries is quite different from that in the U.S. Especially ICT products at the high-tech end of the range, such as

[18] The underlying data material is described in more detail in van Ark, Inklaar and McGuckin (2002), but the estimates are updated for EU-15 and U.S. data (see http://www.ggdc.net/dseries). The present data for the EU-15 and the U.S. are consistent with those published in O'Mahony and van Ark (2003).

[19] The STAN Database uses the international classification ISIC revision 3. This classification is very similar to the one European countries are using, but especially for the U.S. much effort has been made to reconcile differences in industrial classification, see Appendix B of van Ark, Inklaar and McGuckin (2002).

[20] See van Ark, Inklaar and McGuckin (2003) for details on this method, which was originally devised for deflation of ICT investment series by Schreyer (2002).

electronic computers and semiconductors, which show the fastest price declines, are hardly or even not at all represented in the ICT-producing industries of CEE countries. For the CEE countries we therefore present results based on the harmonised deflator, from which we excluded electronic computers and semiconductors. Although such alternatives have a significant impact on the output and productivity estimates of ICT-producing industries, they hardly affect the aggregate estimates for the total economy, as can be seen from the pre-memoria entry in Table 6 below.

Table 5: Employment (Persons Employed) by Industry Group as Share of Total Employment, 1993/1995 and 2001

	EU		US		Czech Rep.		Hungary		Poland		Sl
	1995	2001	1995	2001	1993	2001	1993	2001	1993	2001	199
Total Economy											
ICT Producing Industries	3.5	4.0	3.9	4.6	3.7	4.0	3.9	4.9	2.3	2.4	4
ICT Producing Manufacturing	1.1	1.1	1.3	1.2	1.2	1.5	1.4	2.2	0.8	0.7	1
ICT Producing Services	2.4	2.9	2.6	3.4	2.5	2.5	2.5	2.7	1.5	1.7	2
ICT Using Industries	27.2	27.3	31.0	30.1	26.1	29.2	22.9	25.0	22.2	23.5	21
ICT Using Manufacturing	6.7	6.0	5.3	4.4	10.4	10.0	7.6	8.4	7.3	6.2	9
ICT Using Services	20.6	21.3	25.7	25.7	15.7	19.2	15.3	16.5	14.9	17.4	12
Non-ICT Industries	69.2	68.7	65.1	65.2	70.2	66.8	73.2	70.1	75.5	74.1	74
Non-ICT Manufacturing	11.7	10.8	7.6	6.6	18.7	18.4	16.0	14.5	13.0	11.0	16
Non-ICT Services	43.9	45.7	48.5	49.4	29.6	33.4	38.5	39.8	25.5	27.5	34
Non-ICT Other	13.7	12.1	9.0	9.3	21.9	15.0	18.7	15.9	37.1	35.6	23

Note: Real estate has been excluded

Source: OECD STAN Database; OECD Structural Statistics for Industry and Services; OECD Services Statistics on Value Added and Employment, and additional sources from national accounts of individual countries. For EU countries and OECD, see also van Ark et al. (2002).

Table 6: Labour productivity growth (GDP per person Employed) of ICT-producing, ICT-using and non-ICT industries, 1993/1995-2001

	EU-15 1995-2001	US 1995-2001	Czech 1993-2001	Hungary 1993-2001	Poland 1993-2001	Slovakia 1993-2001
Total Economy	1.3	2.2	2.8	2.4	3.3	2.5
ICT Producing Industries	7.2	9.6	13.0	7.8	5.8	8.5
ICT Producing Manufacturing	11.9	23.0	15.4	7.5	8.1	7.1
ICT Producing Services	5.5	1.8	12.9	8.6	4.6	9.2
ICT Using Industries	1.6	4.6	4.4	1.0	4.8	1.8
ICT Using Manufacturing	1.6	0.1	9.2	7.1	12.0	7.1
ICT Using Services	1.5	5.4	2.3	-0.6	2.3	-1.1
Non-ICT Industries	0.6	-0.2	1.3	2.3	2.4	2.4
Non-ICT Manufacturing	1.3	0.2	5.3	2.6	4.6	3.4
Non-ICT Services	0.2	-0.2	-1.5	2.1	1.9	4.1
Non-ICT Other	1.9	0.7	2.3	2.6	1.3	-1.8
Pro Memoria: Using national ICT deflators						
Total Economy	1.3		2.8	2.9	3.5	2.3
ICT Producing Manufacturing	9.2		14.1	22.1	17.9	-7.4

Notes: Real estate has been excluded from both GDP and Total persons engaged for all countries; For the CEE countries instead of using US ICT deflators, the US ICT deflators exclude prices of computers and semi-conductors.
Source: See Table 5 (see Appendix Table 4 for figures by industry)

Table 7: Contributions to labour productivity growth of ICT-producing, ICT-using and non-ICT industries, 1995-2001

	EU-15 1995-2001	US 1995-2001	Czech 1993-2001	Hungary 1993-2000	Poland 1993-2001	Slovakia 1993-2001
Total Economy	1.34	2.19	2.83	2.41	3.33	2.50
ICT Producing Industries	0.58	0.98	0.68	0.68	0.21	0.15
ICT Producing Manufacturing	0.20	0.73	0.15	0.27	0.06	0.12
ICT Producing Services	0.38	0.25	0.53	0.42	0.15	0.03
ICT Using Industries	0.46	1.17	1.55	0.54	1.57	0.40
ICT Using Manufacturing	-0.01	-0.12	0.67	0.46	0.65	0.98
ICT Using Services	0.47	1.29	0.89	0.07	0.92	-0.58
Non-ICT Industries	0.29	0.06	0.60	1.19	1.56	1.96
Non-ICT Manufacturing	0.01	-0.18	0.94	0.31	0.66	1.84
Non-ICT Services	0.30	0.10	-0.01	0.80	0.75	1.54
Non-ICT Other	-0.01	0.14	-0.33	0.08	0.15	-1.43
Pro Memoria: Using national ICT deflators						
Total Economy						
ICT Producing Manufacturing	0.13		0.16	0.56	0.19	-0.93

Notes: Real estate has been excluded from both GDP and Total persons engaged for all countries. For the CEE countries instead of using US ICT deflators, the US ICT deflators exclude prices of computers and semi-conductors

Source: See Table 5 (see Appendix Table 4 for figures by industry)

The employment share and productivity growth of ICT-producing industries

The main results are shown in Tables 5 to 7. Table 5 shows the shares of each industry group in total employment for the EU-15, the United States, and separately for the Czech Republic, Hungary Poland and Slovakia in 1993/1995 and 2001. The table shows that the employment shares of ICT-producing industries are quite small, but that they tend to be somewhat higher in CEE countries than in the EU-15 and the U.S. in manufacturing industries. These higher shares represent a fair amount of foreign direct investment in particular in Hungary. However, most of the production in these industries does not represent ICT-products at the high-tech end, but rather components and assembly items, for example, television screens, computer monitors, other household electronic equipment, etc..

Indeed Table 6 shows that, even after removing the price declines for the most high-tech ICT-products from the harmonized deflators we applied, the labour productivity growth rates in ICT-producing manufacturing in the CEE countries are still high, reflecting the enormous overhaul in the ICT-producing sector of the CEE economies. But the productivity growth rates in ICT-producing manfacturing are notably lower than in the EU-15 and the U.S.[21] Table 7, however, shows that in Hungary ICT-producing manufacturing contribute as much to aggregate productivity growth than the average EU-15. In this respect it may be argued that these production activities, which largely rest on FDI and strategic alliances between foreign and national firms, have significantly contributed to accelerated productivity growth in Hungary. In the Czech Republic the contribution of ICT-producing services is relatively large. In Poland the contribution of ICT production to aggregate labour productivity growth is much weaker, in particular because of relatively low contribution from telecommunication services.

The employment share and productivity growth of ICT-using industries

Table 5 shows that ICT-using industries account for a much larger share of total employment than ICT-producing industries. Here it is useful to make a distinction between ICT-using manufacturing industries and ICT-using service industries. With the possible exception of Poland (where agriculture – which is included under "Non-ICT other" – is still a dominant sector with a 29% share in total employment in 2001), ICT-using manufacturing industries are more important in terms of employment shares than in the EU-15 or the United States. ICT-using services, though still smaller than in the EU-15 and in particular the U.S., also show an increasing employment share in CEE countries.

One may argue that the greater share of ICT-manufacturing compared to the EU-15 and the U.S. is not necessarily related to ICT, as a high share can be observed for non-ICT industries as well (see Table 5). Table 6, however, shows that productivity growth rates in ICT-manufacturing are in most cases two or more times larger than the productivity growth rates in non-ICT manufacturing. In particular ICT using-industries like transport equipment and electrical machinery exhibit rapid productivity growth (See Appendix Table 4). This is a clear indication that ICT has been an important

[21] The productivity and employment growth rates for individual industries are shown in **Appendix Table 4**. Strikingly, for two of CEE countries, i.e. Hungary and Poland, the harmonized deflators excluding computer and semi-conductors show slower price declines than the national deflators for ICT-producing manufacturing. If one would accept the national deflators, the productivity growth in ICT-producing manufacturing in, for example, Hungary would approach the growth rate of the U.S. which seems somewhat implausible.

source of productivity growth in manufacturing in CEE countries. According to Table 7, ICT-using manufacturing industries in the CEE countries contribute for between 0.46 and 0.98 percentage point to aggregate labour productivity growth between 1993 and 2001, against close to zero for the EU-15 and the U.S.

In ICT-using services, the employment share for CEE countries is considerably smaller than for the EU-15 and the U.S. (Table 5). Table 6 shows that those are the industries where productivity growth rates in the latter two countries have been relatively high, also in comparison with non-ICT services. Productivity growth in ICT-using services in Czech Republic and Poland has also been relatively high, but not in Hungary and Slovakia. The fastest growth rates in the CEE countries are observed in wholesale trade (except for Slovakia), banks (except for Hungary and Slovakia), insurance and securities trade (see Appendix Table 4). These are patterns that are not all that different from the EU-15 and the U.S., except that in the latter productivity growth was also relatively high in the retail industry.[22] The somewhat mixed picture of productivity growth in ICT-using services in the CEE countries is also reflected in the contributions of this industry group to aggregate productivity growth, which ranges from -0.58 percentage points to 0.98 percentage points in Poland (Table 7). The contribution for Poland (and also for the Czech Republic) is significantly higher than in the EU-15 but lower than in the U.S.

Conclusions

Although there are differences between countries, which partly reflect differences in industry composition and partly measurement problems, three main conclusions can be derived from this analysis of labour productivity growth at industry level. Firstly, only in Hungary ICT-producing industries have contributed significantly more to productivity growth than in the EU-15. In this respect, investment in the production of "new economy" products cannot be seen as a major direct source of catch-up. Secondly, ICT-using manufacturing industries have exploited a large catch-up potential, which may be largely related to significant restructuring. As manufacturing may become less important in terms of employment and GDP shares, it may only represent a temporary catch-up effect. Thirdly, although the picture of productivity improvements in ICT-using services is mixed, there is evidence of a significant remaining potential for catch-up and convergence in these industries.

5. Determinants of ICT Diffusion and the Convergence Process in CEE Countries

The two previous sections presented contributions of ICT to the catching-up process on the aggregate and industry-level in the CEE and EU countries. We concluded that the evidence points in the direction of a role for ICT as a major source of growth in CEE countries, and in the manufacturing sector even as a (temporary) source of convergence. The more lasting contribution of ICT to growth, including total factor productivity, will more likely depend on the existence of a conducive environment for ICT investment in services and the adoption of productivity enhancing practices.

[22] The negative growth rates in banks and retail trade in Hungary are responsible for the negative productivity growth rates of the ICT-using sector as a whole.

There is a relatively large literature analyzing the determinants of adoption and diffusion of ICT on both aggregate and industry-level in advanced countries.[23] These studies show that low level of competition in product and labour markets coupled with limited innovation efforts, few ICT skills of the workforce and insufficient flexibility to reform business organizations negatively impact the pace of ICT diffusion as well as the productivity effects from the use of ICT.

Unfortunately there are not many studies that focus on the determinants of ICT adoption in the CEE countries. Piatkowski (2002) directly focuses on the economic and institutional determinants of investment in ICT.[24] He constructs a "New Economy Indicator", which is aimed at measuring the capability of 27 transition economies to exploit the potential of ICT to accelerate the long-term economic growth and catching-up with developed countries.

On the basis of the original New Economy Indicator for 2000, Slovenia scored the highest, followed by the Czech Republic, Hungary, Slovakia and Poland. Albania, Bosnia and Herzegovina, and FR Yugoslavia occupied the bottom of the table (Piatkowski, 2002). The ranking showed that the post-socialist countries which were most advanced in the transition process also received the highest scores. Since the level of development of the economic and institutional infrastructure is seen as crucial for innovation and technological change, Piatkowski (2002) argued that the most advanced CEE countries were also the most likely to benefit from the use of ICT and thus accelerate catching-up on the EU-15 countries.

For the purpose of the present paper, and in order to analyse its relationship to the contribution of ICT capital to labour productivity growth, the New Economy Indicator has been updated, slightly reconstructed and extended to cover both the CEE and EU-15 countries featured in this study. The New Economy Indicator comprises of ten variables, which are seen to be the most pertinent for diffusion of ICT and its profitable use. Table 8 shows the variables and sources of the components of the indicator.

[23] See, for example, OECD (2001, 2003).
[24] Muller and Salsas (2003) analyze the determinants of the Internet use, while Clarke (2003) looks at the factors impacting firms' access to the Internet.

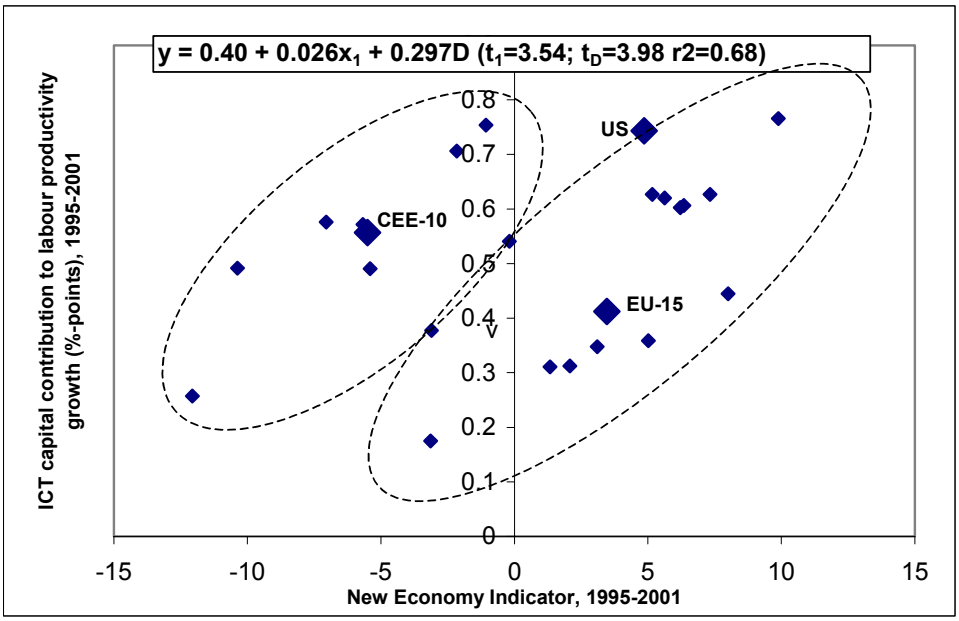
Table 8: Variables and data sources for the New Economy Indicator

Factor	Variable	Source
1. Quality of regulations and contract enforcement	Sum of World Bank Regulatory Quality and Rule of Law Indicator*	Kaufmann et al. (2003)
2. Infrastructure	Sum of total number of telephone lines (main and cellular) and PCs per 1000 persons	WDI 2003
3. Trade openness	Share of trade in GDP (in %)	WDI 2003
4. Development of financial markets	Domestic credit to private sector (% of GDP)	WDI 2003
5. R&D spending	Annual R&D spending (% of GDP)	Eurostat 2003
6. Quality of human capital	Public spending on education (% of GDP)	Eurostat 2003
7. Labour market flexibility	Unemployment rate (in %)	WDI 2003
8. Product market flexibility	Product market regulation indicator (Nicoletti et al. 2000)**	EBRD 2003
9. Openness to foreign investment	FDI (% of GDP)	WDI 2003
10. Macroeconomic stability	Inflation (CPI) (in %)	WDI 2003

*Regulatory Quality and Rule of Law are available for 1996, 1998, 2000 and 2002. 1995 was assumed to equal 1996; 1997, 1999 and 2001 were calculated as averages of 1996-98, 1998-2000 and 2000-02, respectively.

** The indicator to Slovakia is assumed to equal the Czech Republic's, while Slovenia's score equals the value for Hungary. Indicators for Bulgaria, Romania, and Russia are based on the score for Poland multiplied by 1.20 on the basis of the "Competition Indicator" from EBRD 2003.

Figure 5: New Economy Indicator and ICT Capital Contribution to Labour Productivity Growth, 1995-2001



Note: x1 refers to the New Economy Indicator, D refers to a dummy for CEE countries.
Source: New Economy Indicator, see Table 8 and Appendix Table 5; ICT contribution to labour productivity growth, see Figure 4.

Following Piatkowski (2002) and based on the competitiveness indicator developed by Zinnes et al. (2001, p. 322), the aggregate New Economy Indicator is constructed in the following way:
variables are selected, ensuring that each of them is either entirely positively or negatively related to the main concept;
if variables are negatively correlated (like inflation), they are multiplied by –1 to insure that always 'more is better';
variables are standardized. The sample mean is subtracted from each observation and then the result is divided by a sample standard deviation. This implies a mean of zero and a standard deviation of one across countries in the sample. Hence, all results are comparable and can be aggregated. The final scores of the New Economy Indicator represent a sum of values of all ten variables for each country.

Appendix Table 5 shows the New Economy Indicator for each of the countries based on average scores for 1995-2001. As could be expected, the value of the New Economy Indicator for the EU-15 is higher than the CEE countries. Sweden, the Netherlands and Denmark reported the highest values, whereas Bulgaria, Romania and Russia showed the lowest ranking. The difference in values reflects the much better developed institutions in the EU-15, higher spending on R&D, higher level of liberalization of product markets and a more stable macroeconomic environment.

Relating the New Economy Indicator to the contribution of ICT capital to labour productivity growth suggests a clear distinction between CEE countries and EU-15 countries (Figure 5). Even at very low

levels of the New Economy Indicator, the average absolute contribution of ICT capital to labour productivity growth in CEE countries is as high as for the EU-15. This might indicate that, despite a less well performing environment, the process of restructuring itself has led to the relatively high contribution of ICT capital. As argued above, much of the restructuring has taken place in manufacturing where ICT might have played an important role in strengthening downsizing and efficiency. Nevertheless within the group of CEE countries, there was a clearly positive relationship between the new economy indicator and the ICT capital contribution.

For the EU-15 countries the relationship between the New Economy Indicator is also strongly positive. This is in contrast to the relationship between the productivity level and the ICT capital contribution as shown in Figure 4. Combining the evidence from the two charts with the industry analysis in Section 4 suggests that the New Economy Indicator is important from the perspective of ICT diffusion, in particular in services, which is the key to growth in the EU-15.

Interestingly, various experiments by correlating individual indicators, such as R&D spending, FDI and product market regulation, to the ICT capital contribution (which in turns contributes to labour productivity growth) do not provide results, which are as strong as those for the New Economy Indicator. This suggests that there is a strong complementarity between the various factors, and that single-cause explanations are unlikely to provide strong effects on growth.

6. Conclusions

This paper has investigated how the productivity performance of the CEE countries vis-à-vis the EU-15 has evolved during the 1990s, and whether on the basis of the experience of the past decade, a process of convergence or divergence should be expected for the coming period. In Section 2 we showed that a continued decline in labour intensity in the CEE countries and a rise in EU-15 countries implies a further convergence of labour productivity in the near future. In Section 3 the role of ICT capital was highlighted as an important source of growth during the 1990s. We found that ICT capital in the CEE-10 has contributed as much to labour productivity growth as for the EU-15. This observation was further elaborated in Section 4, which identified ICT-using manufacturing industries as key to the restructuring process and an important, but probably temporary source of convergence. For services there are as yet only mixed signs on the contribution of ICT investment to growth.

The New Economy Indicator in the Section 5 suggests that competition, innovation and macroeconomic stability together provide a conducive environment for growth. Hence as such the New Economy Indicator provides an insight into how economic policy can contribute to the realization of growth potential of the "new economy" in both the New and Old Europe. However, it should also be stressed that from the perspective of convergence analysis, many CEE countries were able to increase ICT intensity and raise the ICT contribution to productivity in spite of a much less developed economic, regulatory, and institutional environment than in the EU countries (with notable exceptions of Italy, Greece and Spain). This may be characteristic of the first phase of the transition and convergence during which restructuring (in particular in manufacturing) could take place even without the existence of such an environment. However, as the potential to realize productivity growth from ICT-investment in major using sectors, in particular in services, is still large, it is likely

that these reforms are much more needed, as is also clear from comparisons between the traditional OECD countries (OECD, 2001; 2003).

Although our conclusions generally give more support to the convergence hypothesis than to the divergence hypothesis, we argue that the convergence process may slow as the productive implementation of ICT in services is more complicated and requires larger changes in the economic environments of CEE countries. Further income and productivity convergence of the CEE countries with the EU will therefore depend on continued progress in the creation of modern institutions, implementation of market-oriented policy reforms aimed at strengthening competition, increased innovation, improvements in the quality of the human capital and an enhancement of the comprehensiveness and effectiveness of regulations.

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Appendix Table 1: Growth of Real GDP, GDP per capita, GDP per person Employed and Employment to Population Ratio, 1995-2002 (average annual growth rates)

	Real GDP	GDP per head of population	GDP per person employed	Employment to Pop. Ratio
EU-15	2.3	2.1	1.0	1.0
Austria	2.2	1.9	2.1	-0.2
Belgium	2.1	1.9	1.2	0.7
Denmark	2.4	2.0	1.7	0.3
Finland	3.8	3.6	2.0	1.5
France	2.4	1.9	0.9	1.0
Germany	1.4	1.3	1.2	0.1
Greece	3.6	3.3	3.1	0.3
Ireland	8.5	7.5	4.0	3.5
Italy	1.7	1.5	0.5	1.0
Luxembourg	5.2	4.0	1.1	2.8
Netherlands	2.8	2.3	0.0	2.2
Portugal	3.0	2.9	0.9	1.9
Spain	3.4	3.2	-0.4	3.6
Sweden	2.7	2.6	1.8	0.8
United Kingdom	2.8	2.4	1.7	0.7
CEE-10	2.9	3.1	3.9	-0.8
Bulgaria	0.6	1.8	2.2	-0.3
Czech Republic	1.6	1.7	2.0	-0.3
Hungary	3.8	4.1	2.8	1.3
Poland	3.9	3.9	4.9	-1.0
Romania	0.6	0.8	3.0	-2.2
Slovakia	3.7	3.6	3.8	-0.3
Slovenia	3.8	3.7	3.1	0.5
Estonia	4.7	5.4	5.2	0.3
Latvia	4.9	5.8	5.7	0.1
Lithuania	4.7	5.0	5.1	-0.1
EU-25	2.4	2.2	1.4	0.8
United States	3.2	2.1	2.0	0.1

Source: Groningen Growth and Development Centre (www.ggdc.net) (January 2004)

Appendix Table 2: GDP per capita, GDP per person Employed and Employment to Population Ratio, 1995 and 2002

	GDP per head of Population (1999 US$ at EKS PPP)		GDP per person employed (1999 US$ at EKS PPP)	
	1995	2002	1995	2002
EU-15	21263	24581	52601	56548
Austria	23430	26820	50530	58461
Belgium	22591	25877	61630	66988
Denmark	25231	29073	51471	58112
Finland	19692	25267	48106	55420
France	21782	24925	57098	60826
Germany	23306	25527	53191	57811
Greece	13380	16908	36737	45578
Ireland	18603	31392	52814	69952
Italy	22570	25105	58779	60879
Luxembourg	36054	47557	69147	74772
Netherlands	23364	27400	53667	53833
Portugal	14604	17856	33227	35470
Spain	16388	20521	52275	50966
Sweden	21702	26080	47221	53739
United Kingdom	21167	25067	48310	54435
CEE-10	8045	9988	19691	25806
Bulgaria	6832	7751	17218	20015
Czech Republic	13263	14904	27902	32107
Hungary	9715	12978	27979	34148
Poland	7588	9970	19802	27943
Romania	5862	6199	14012	17264
Slovakia	9859	12644	24622	32234
Slovenia	13942	18030	35725	44507
Estonia	6984	10202	13209	18955
Latvia	5329	7990	9855	14710
Lithuania	6312	8943	12419	17718
EU-25	19188	22417	47406	52331
United States	29339	34097	62208	71574

Source: Groningen Growth and Development Centre (www.ggdc.net) (January 2004)

Appendix Table 3: Employment-Population Ratios, Labour Force Participation Rates and Total Hours to Potential Hours (a), 1995 and 2002

	Employment to Population Ration (%)		Labour Force to Population 15-64 yrs		Total Hours to Potential Hours (%) (a)	
	1995	2002	1995	2002	1995	2002
EU-15	0.404	0.435	0.678	0.704	0.349	0.367
Austria	0.464	0.459	0.721	0.723	0.384	0.368
Belgium	0.367	0.386	0.644	0.660	0.325	0.331
Denmark	0.490	0.500	0.794	0.798	0.390	0.405
Finland	0.409	0.456	0.736	0.756	0.369	0.389
France	0.381	0.410	0.675	0.702	0.323	0.337
Germany	0.438	0.442	0.709	0.723	0.350	0.342
Greece	0.364	0.371	0.601	0.606	0.371	0.378
Ireland	0.352	0.449	0.631	0.692	0.361	0.394
Italy	0.384	0.412	0.588	0.621	0.330	0.356
Luxembourg	0.521	0.636	0.788	0.980	0.430	0.533
Netherlands	0.435	0.509	0.701	0.760	0.310	0.355
Portugal	0.440	0.503	0.700	0.767	0.420	0.443
Spain	0.313	0.403	0.613	0.662	0.302	0.376
Sweden	0.460	0.485	0.781	0.775	0.416	0.421
United Kingdom	0.438	0.461	0.749	0.759	0.401	0.413
CEE-10	0.370	0.350	0.687	0.654	0.462	0.422
Bulgaria	0.397	0.387	0.640	0.690	0.455	0.448
Czech Republic	0.475	0.464	0.734	0.727	0.496	0.457
Hungary	0.347	0.380	0.591	0.592	0.325	0.348
Poland	0.383	0.357	0.674	0.648	0.455	0.406
Romania	0.418	0.359	0.691	0.571	0.483	0.411
Slovakia	0.400	0.392	0.692	0.700	0.428	0.401
Slovenia	0.390	0.405	0.607	0.620	0.386	0.399
Estonia	0.529	0.538	0.871	0.861	0.610	0.584
Latvia	0.541	0.543	0.919	0.890	0.653	0.612
Lithuania	0.508	0.505	0.856	0.832	0.619	0.574
EU-25	0.405	0.428	0.680	0.693	0.374	0.379
United States	0.472	0.476	0.777	0.759	0.480	0.477

(a) potential hours are based on working age population times 2,800 working hours per year

Source: Groningen Growth and Development Centre (www.ggdc.net), OECD Labour Force Statistics, various issues and Eurostat, Employment in Europe 2003.

Appendix Table 4: Labour Productivity and Employment Growth by Industry

		GDP per person employed							Persons Employed						
ISIC		EU	US		Czech Rep.	Hungary	Poland[1]	Slovakia	EU	US		Czech Rep.	Hungary	Poland[1]	Slovakia
Rev3		1995-2001	1995-2001		1993-2001	1993-2001	1993-2001	1993-2001	1995-2001	1995-2001		1993-2001	1993-2001	1993-2001	1993-2001
	Total Economy	**1.3**	**2.2**		**2.8**	**2.4**	**3.3**	**2.5**	**1.3**	**1.6**		**-0.5**	**0.2**	**0.5**	**-0.3**
	ICT Producing Industries	**7.2**	**9.6**		**13.0**	**7.8**	**5.8**	**8.5**	**3.2**	**3.8**		**0.3**	**3.1**	**0.0**	**0.0**
	Manufacturing	**11.9**	**23.0**		**15.4**	**7.5**	**8.1**	**7.1**	**0.6**	**0.2**		**1.7**	**5.8**	**-1.4**	**1.3**
30	Computers	44.5	47.1		32.2	11.3	16.9	17.3	-0.7	-4.1		10.6	18.6	2.7	0.7
313	Fiber optics	0.1	3.1		-2.3	-7.7	-5.6	12.1	0.4	-1.0		6.1	7.8	3.7	11.4
321	Semiconductors	56.6	51.3		26.4	15.5	3.2	-8.0	2.7	2.3		5.0	10.0	-9.0	4.8
322	Communication eq.	0.5	-2.0		34.4	16.5	13.0	2.7	0.8	1.2		-2.0	0.6	0.3	-2.1
323	Radio and TV eq.	-7.2	-9.1		47.1	18.6	19.6	-1.4	-1.7	-4.0		-10.4	9.4	-6.3	-3.7
331	Instruments	-7.8	-6.8		8.1	0.5	4.4	3.9	1.0	0.2		1.3	-4.9	-0.1	-0.1
	Services	**5.5**	**1.8**		**12.9**	**8.6**	**4.6**	**9.2**	**4.3**	**5.7**		**-0.5**	**1.3**	**1.5**	**0.0**
64	Telecommunications	8.5	6.6		16.0	7.3	4.2	9.3	1.0	1.4		-1.6	-0.1	0.5	-0.1
72	Computer services	1.4	-3.9		4.2	13.2	3.9	10.1	9.5	11.1		1.9	6.9	6.9	0.6
	ICT Using Industries[a]	**1.6**	**4.6**		**4.4**	**1.0**	**4.8**	**1.8**	**1.4**	**0.8**		**0.9**	**1.3**	**0.0**	**0.0**
	Manufacturing	**1.6**	**0.1**		**9.2**	**7.1**	**12.0**	**7.1**	**-0.4**	**-1.4**		**-0.9**	**1.5**	**-1.6**	**-2.6**
18	Apparel	3.4	5.3		5.1	2.6	5.2	2.6	-4.1	-9.7		-1.8	-0.4	-2.3	1.8
22	Printing & Publishing	1.6	-0.7		1.8	3.6	12.0	25.3	-0.4	-1.0		1.8	2.4	5.7	-2.2
29	Machinery	0.9	-2.8		6.3	10.8	15.4	-2.1	0.3	-0.4		-2.6	-3.1	-4.9	-6.7
31-313	Electrical machinery	1.8	-3.9		8.7	10.9	7.0	14.2	0.1	-1.5		3.1	10.0	0.1	4.1
33-331	Watches & instruments	3.2	4.1		17.2	3.3	11.3	11.2	-0.4	-2.0		0.7	-1.3	-6.8	-3.2
351	Ships	1.6	2.6		33.1	45.9	15.0	n.a.	-0.3	0.4		-10.6	-2.7	-1.6	n.a.
353	Aircraft	-0.2	2.6		33.1	10.8	17.9	2.0	2.5	-1.3		-0.4	-8.2	-8.0	-14.2

352+359	Railroad and other	2.4	4.4		33.1	20.9	22.0	-1.4		-0.9	4.3		-8.0	3.1	-5.5	5.6
36-37	Misc. manufacturing	1.2	2.3		15.1	2.5	9.4	18.1		0.0	0.0		-0.6	2.4	1.7	-3.2
		GDP per person employed								**Persons Employed**						
ISIC		EU	US		Czech Rep.	Hungary	Poland[1]	Slovakia		EU	US		Czech Rep.	Hungary	Poland[1]	Slovakia
Rev3		1995-2001	1995-2001		1993-2001	1993-2001	1993-2001	1993-2001		1995-2001	1995-2001		1993-2001	1993-2001	1993-2001	1993-2001
	Services	**1.5**	**5.4**		**2.3**	**-0.6**	**2.3**	**-1.1**		**1.9**	**1.2**		**2.0**	**1.2**	**2.4**	**2.9**
51	Wholesale trade	1.5	7.4		7.2	5.9	3.7	-3.2		1.7	0.6		1.4	-3.2	1.9	5.5
52	Retail trade	0.8	6.3		0.1	-2.4	1.7	-0.8		1.3	0.9		0.5	2.2	1.0	1.6
65	Banks	3.9	4.2		3.9	-5.9	18.7	-4.6		0.1	1.6		3.5	1.4	1.3	1.1
66	Insurance	-0.5	0.5		7.2	12.6	14.0	26.5		0.7	0.9		6.0	-0.5	3.1	23.2
67	Securities trade	0.0	10.3		11.7	11.9	9.8	8.7		3.3	3.4		13.0	4.8	24.5	27.9
71	Renting of machinery	1.6	5.9		-14.5	-1.3	3.4	-3.6		5.3	2.8		13.5	-0.8	4.1	3.9
73	R&D	-1.5	2.4		-0.7	-1.9	-3.0	10.1		2.0	1.5		-3.7	1.0	-2.2	-3.9
741-743	Professional services	0.3	0.6		-4.5	0.1	-7.1	-0.5		4.5	2.2		4.8	1.4	12.5	2.7
	Non-ICT Industries	**0.6**	**-0.2**		**1.3**	**2.3**	**2.4**	**2.4**		**1.2**	**1.8**		**-1.1**	**-0.4**	**0.0**	**0.0**
	Manufacturing	**1.3**	**0.2**		**5.3**	**2.6**	**4.6**	**3.4**		**0.1**	**-0.8**		**-0.7**	**-1.1**	**-1.5**	**-1.8**
15-16	Food & beverages	0.3	-5.9		11.1	-0.7	3.9	0.1		0.2	0.1		-0.8	-2.2	-0.4	-1.2
17	Textiles	1.9	1.9		4.4	10.3	9.0	8.9		-2.1	-5.5		-3.1	-6.2	-8.6	-3.6
19	Leather	0.9	-0.3		7.6	0.7	10.4	15.4		-2.6	-8.6		-7.2	-1.6	-7.4	-6.7
20	Wood	1.8	-1.0		6.8	1.3	0.1	15.5		-0.3	-0.1		-0.3	2.3	1.8	-3.1
21	Paper	2.6	0.8		0.6	8.7	3.9	11.3		-0.4	-1.6		-4.2	0.9	1.2	-2.7
23	Petroleum & coal	-1.1	0.8		-4.8	-10.8	11.9	11.0		-0.7	-2.2		-15.9	-4.1	-2.9	-3.3
24	Chemicals	3.4	1.4		-1.8	1.2	-6.6	6.2		-0.5	-0.3		-0.4	-6.4	-2.9	-6.4
25	Rubber & plastics	1.2	3.7		6.8	5.0	6.7	3.2		1.0	-0.5		4.5	5.7	4.1	0.5
26	Stone, clay & glass	1.2	-0.3		7.4	6.1	16.8	7.3		0.3	0.8		0.6	0.3	-1.5	-1.5
27	Basic metals	0.9	2.8		0.4	6.0	6.4	-11.4		-1.2	-1.5		-4.2	-3.3	-9.9	-0.1

28	Fabricated metals	0.8	0.1		7.4	6.1	5.1	-4.0		0.6	0.2		0.5	4.0	3.2	3.2
34	Motor vehicles	0.3	1.2		7.1	15.7	4.5	6.9		2.1	-0.4		3.4	3.3	-2.1	1.0
		GDP per person employed								**Persons Employed**						
ISIC		EU	US		Czech Rep.	Hungary	Poland[1]	Slovakia		EU	US		Czech Rep.	Hungary	Poland[1]	Slovakia
Rev3		1995-2001	1995-2001		1993-2001	1993-2001	1993-2001	1993-2001		1995-2001	1995-2001		1993-2001	1993-2001	1993-2001	1993-2001
	Services	**0.2**	**-0.2**		**-1.5**	**2.1**	**1.9**	**4.1**		**2.0**	**2.1**		**1.0**	**0.6**	**1.5**	**0.9**
50	Repairs	0.4	-7.3		-2.4	0.5	4.1	-1.6		1.9	7.1		7.1	9.4	3.1	5.9
55	Hotels & restaurants	-1.1	-0.7		1.5	-1.1	5.5	5.5		2.6	2.2		2.9	3.3	3.5	0.4
60	Inland transport	2.0	0.3		-2.1	1.6	5.6	2.7		0.6	2.1		-1.2	-1.4	-1.1	-0.9
61	Water transport	2.3	1.0		-11.0	-7.9	15.7	1.4		-0.3	1.8		-7.8	-0.2	-13.1	-1.4
62	Air transport	3.2	1.1		5.9	1.9	1.0	2.6		4.3	3.1		-2.0	-0.7	1.6	-1.4
63	Supporting activities	0.9	3.0		-5.0	-1.5	4.6	4.2		3.5	1.8		3.9	0.5	-2.0	0.7
70	Real estate															
74.9	Other business services	-1.4	1.4		-2.2	-2.2	-7.1	5.1		6.2	4.7		2.0	9.6	12.5	3.6
75	Government	0.6	0.5		-3.7	2.8	-2.4	7.3		0.0	0.9		2.6	1.3	6.3	2.3
80	Education	-0.2	-1.7		-1.7	4.0	1.2	0.5		1.3	2.1		-1.0	-1.3	1.3	-1.1
85	Health	0.6	0.1		-1.3	3.6	1.4	4.4		1.7	1.9		1.1	-0.3	-0.9	1.6
90-93	Personal & social serv.	0.1	-0.2		-2.1	-0.4	1.9	5.7		2.5	1.2		1.3	-0.7	0.1	1.9
95	Private households	0.0	-0.9		n.a.	n.a.	n.a.	n.a.		2.4	-2.2		n.a.	n.a.	n.a.	23.5
	Other non-ICT industries	**1.9**	**0.7**		**2.3**	**2.6**	**1.3**	**-1.8**		**-0.6**	**2.1**		**-5.2**	**-1.9**	**0.0**	**-2.7**
01	Agriculture	3.2	8.7		7.9	4.5	-2.3	4.3		-1.8	0.1		-8.4	-4.8	0.8	-4.1
02	Forestry	2.2	3.4		9.6	5.5	-3.3	6.1		-2.1	1.7		-9.3	-4.8	-0.1	-4.5
05	Fishing	0.0	13.2		12.8	-3.0	11.5	2.4		-0.2	-5.6		-2.4	7.7	-8.7	-2.1
10-14	Mining	3.5	-0.7		7.7	6.0	6.0	3.4		-4.1	-0.3		-9.5	-14.7	-8.0	-2.5

40-41	Utilities	5.3	-0.1		0.1	2.1	4.8	-19.4		-3.0	-1.0		-0.8	-3.4	-1.4	1.3
45	Construction	0.5	-0.1		-3.3	0.2	3.6	3.6		0.5	3.7		-3.2	3.4	-0.1	-2.4

Appendix Table 5: The New Economy Indicator: values for the CEE countries, EU-15 and the US, 1995-2001 average

Country	Rank	Value 1995-2001	Regulations and law enforcement	Infrastructure	Trade openess	Financial system	R&D spending	Human Capital	Labor marker flexibility	Product market flexibility	Openness to foreign investment	Macroeconomic stability
Sweden	1	9,882	0,818	1,724	- 0,067	0,541	2,273	1,884	0,334	0,641	1,257	0,476
Netherlands	2	8,001	1,035	0,765	0,975	1,197	0,513	- 0,195	1,099	0,641	1,600	0,370
Denmark	3	7,331	0,914	1,439	- 0,278	- 0,217	0,614	2,453	0,898	0,641	0,462	0,404
Ireland	5	6,343	0,830	0,300	2,102	0,554	- 0,262	- 0,213	0,245	1,240	1,228	0,318
UK	4	6,210	0,977	0,710	- 0,716	1,395	0,393	- 0,403	0,634	1,539	1,283	0,397
Belgium	6	5,624	0,254	0,257	1,843	0,253	0,467	0,810	0,161	0,142	1,006	0,430
Finland	9	5,162	1,109	1,268	- 0,355	- 0,271	1,544	1,048	- 0,687	0,342	0,744	0,420
Austria	8	5,021	1,108	0,439	0,163	0,840	0,283	0,643	1,095	0,641	- 0,625	0,433
USA	7	4,857	0,754	1,260	- 1,615	1,510	1,201	- 0,239	1,098	1,040	- 0,540	0,387
Germany	10	3,105	0,720	0,526	- 0,708	1,166	0,928	- 0,416	0,120	0,641	- 0,319	0,446
Portugal	11	2,076	0,215	- 0,187	- 0,347	0,854	- 0,860	0,422	0,902	0,342	0,390	0,345
France	12	1,340	0,160	0,410	- 0,929	0,439	0,784	0,659	- 0,509	- 0,057	- 0,083	0,466
Slovenia	13	- 0,180	- 0,406	- 0,243	0,925	- 0,865	- 0,054	0,540	0,445	0,442	- 0,930	- 0,034
Czech Republic	14	- 1,060	- 0,482	- 0,714	1,148	- 0,043	- 0,309	- 0,485	0,711	- 0,856	- 0,218	0,187
Hungary	15	- 2,163	- 0,202	- 0,880	0,483	- 1,029	- 0,792	- 0,331	0,295	0,442	0,085	- 0,233
Italy	17	- 3,102	- 0,273	0,199	- 0,890	- 0,072	- 0,468	- 0,298	- 0,488	- 0,257	- 0,942	0,386
Spain	16	- 3,141	0,244	- 0,282	- 0,797	0,477	- 0,647	- 0,499	- 2,182	0,442	- 0,255	0,358
Greece	18	- 5,399	- 0,382	- 0,117	- 0,936	- 0,527	- 0,946	- 1,409	- 0,240	- 0,157	- 0,975	0,290
Slovakia	19	- 5,670	- 1,051	- 1,060	1,306	- 0,857	- 0,717	- 0,531	- 1,323	- 0,856	- 0,593	0,012
Poland	20	- 7,042	- 0,674	- 1,352	- 0,707	- 1,212	- 0,828	0,107	- 0,616	- 1,255	- 0,405	- 0,099
Bulgaria	21	- 10,372	- 1,355	- 1,197	0,611	- 1,284	- 0,319	- 1,427	- 1,470	- 1,913	- 0,500	- 1,517
Romania	22	- 12,063	- 1,670	- 1,653	- 0,504	- 1,438	- 1,025	- 1,388	0,482	- 1,913	- 0,763	- 2,191

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